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DRL No. T-2192
DRL Line Item No. 3
DRD No. SE-1299T
CR0009-1039

Power Reactant Storage Assembly (PRSA)
(Space Shuttle)

PRSA Hydrogen and Oxygen DVT Tank Refurbishment - Final Report

15 July 1993

Ball Electro-Optics and Cryogenics Division
Ball Aerospace and Communications Group
Boulder, Colorado 80306-1062

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ABSTRACT

The Power Reactant Storage Assembly (PRSA) liquid hydrogen Development Verification Test (H_2 DVT) tank assembly (Beech Aircraft Corporation P/N 15548-0116-1, S/N 07399000SHT0001) and liquid oxygen (O_2) DVT tank assembly (Beech Aircraft Corporation P/N 15548-0115-1, S/N 07399000SXT0001) were refurbished by Ball Electro-Optics and Cryogenics Division to provide NASA JSC, Propulsion and Power Division, the capability of performing engineering tests. The refurbishments incorporated the latest flight configuration hardware and avionics changes necessary to make the tanks function like flight articles. This final report summarizes these refurbishment activities. Also included are up-to-date records of the pressure time and cycle histories.

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1. DEFINITIONS

ABCR	As-Built Configuration Record
Amb	Ambient
BAC	Beech Aircraft Corporation
BACG	Ball Aerospace and Communications Group (formerly BASG)
BASG	Ball Aerospace Systems Group
BECD	Ball Electro-Optics and Cryogenics Division
BMS	Ball Material Specification
C&DM	Configuration and Data Management
CAT	Component Acceptance Test
COTR	Contracting Office Technical Representative
CRC	Cryogenic Research Center
Cryo	Cryogenic
DVT	Design Verification and Test
EDO	Extended Duration Orbiter
EIAD	End item Acceptance Data-Package
EIAT	End Item Acceptance Test
GN_2	Gaseous Nitrogen
H_2	Hydrogen
JSC	Johnson Space Center
LDO	Long Duration Orbiter
MLI	Multilayer Insulation
MRB	Material Review Board
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
O_2	Oxygen
P/N	Part number
PRSA	Power Reactant Storage Assembly
RI	Rockwell International
S/N	Serial number
SCD	Source Control Drawing
SD	Space Division
SODB	Shuttle Operational Data Book
SOW	Statement of Work
WBS	Work Breakdown Structure

2. SUMMARY

This final report summarizes the refurbishment activities performed on the Power Reactant Storage Assembly (PRSA) liquid hydrogen Design Verification and Test (H_2 DVT) tank assembly (BAC P/N 15548-0116-1, S/N 07399000SHT0001) and the liquid oxygen (O_2) DVT tank assembly (BAC P/N 15548-0115-1, S/N 07399000SXT0001) by BECD. The purpose of the refurbishments was to provide NASA JSC, Propulsion and Power Division, the capability of performing engineering tests. The refurbishments incorporated the latest flight configuration hardware and avionics changes necessary to allow the tanks to function like flight articles. The configuration of the tanks following refurbishment meets the functional requirements of RI P/N MC282-0112-0200[1] for the H_2 DVT and RI P/N MC282-0112-0100[2] for the O_2 DVT. The refurbishment activity included End Item Acceptance Testing which was successfully completed without incident.

As recommended in the proposal[3], the Neck Plug was not removed on either tank and, therefore, the Pressure Vessel was not opened. Thus for the H_2 DVT, the original, 0.5 inch short, Quantity Gauge Probe was reused resulting in a 0.052 Vdc lower than nominal output voltage from the H_2 Signal Conditioner. In addition, the shorter O_2 DVT Quantity Gauge Probe was reused. However, the output from both systems are within the allowable accuracy as defined in the RI Procurement Specification[4].

The O_2 DVT Signal Conditioner was refurbished and the Quantity Gaging System is now operating properly.

The O_2 DVT No. 2 Heater Assembly exhibits a higher than specified resistance due to a pre-existing condition. However, this may be compensated for by an increase in the bus voltage. NASA JSC was informed of this condition[5] and concurred that the condition was acceptable and that no changes to the heater were required[6].

It should be noted that H_2 DVT End Item Acceptance Testing was performed using a refurbished H_2 Qualification Unit Signal Conditioner. This was not realized until the test was completed. Thereupon, the H_2 DVT Signal Conditioner was tested, found to not require refurbishment, and installed onto the H_2 DVT tank. The H_2 Qualification Unit Signal Conditioner was properly identified and reinstalled onto the H_2 Qualification Unit tank. As the Signal Conditioners are Line Replaceable Units, no further action was deemed warranted.

In addition to the tank refurbishment, a hydrogen tank DVT External Multilayer Insulation Blanket was designed, fabricated, and delivered for LDO testing.

3. RESULTS

The refurbishment activities performed on the H_2 DVT and O_2 DVT PRSA tank assemblies have resulted in flight-like Engineering Test Articles. Due to the short Quantity Gauge Probe in the H_2 DVT, the output voltage from the H_2 Signal Conditioner Assembly will be 0.052 Vdc below nominal values, but still within specification requirements. A search of the pressure time and cycle histories for both tanks was performed and are included for reference.

4. CONCLUSIONS

Successful in-process and End Item Acceptance Testing concludes that the H_2 DVT and O_2 DVT PRSA tank assemblies may be used for Engineering Test Article usage (see Recommendations).

5. RECOMMENDATIONS

BECD can not take responsibility for the accuracy of the tabulated, non-BECD performed pressure time and cycle histories. It is recommended that all future users of the H_2 DVT and O_2 DVT tank assemblies be made aware of the total number of Pressure Vessel cycles performed to date and maintain records of additional pressure cycles. The approximate total number of cycles performed on the H_2 DVT is interpreted by BECD Engineering as being at one-third of the design life of 300 cycles. This assumes that 300 pressure cycles is equivalent to 100 missions[7]; and that ambient (temperature) and cryogenic (temperature) cycles are considered to be equally stressful in the pressure time and cycle count. The approximate total number of cycles performed on the O_2 DVT is interpreted by BECD Engineering as being at one-fourth of the design life of 300 cycles, with the same assumptions.

6. INTRODUCTION

6.1 Scope. The purpose of this document is to provide a final report and technical summary of the activities, and the results of the refurbishment and testing of the H_2 DVT Tank Assembly, BAC P/N 15548-0116-1, S/N 07399000SHT0001, and the O_2 DVT Tank Assembly, BAC P/N 15548-0115-1, S/N 07399000SXT0001. The purpose of the refurbishment was to provide NASA JSC with an H_2 DVT and an O_2 DVT which have incorporated the hardware and avionics changes that have occurred since the date the tanks were originally assembled. These changes were to provide NASA JSC, Propulsion and Power Division, the capability to perform engineering tests as required to:[8]

a. Investigate PRSA tank performance characteristics.

b. Obtain PRSA system operational data to support the SODB.

c. Conduct certain design change development programs when needed.

d. Investigate in-flight anomalies if they occur.

This report will present a technical synopsis of each applicable paragraph of the Statement of Work in itemized format.

7. DISCUSSION

7.1 SOW Purpose (1.0). The objective of this effort was to refurbish the PRSA H_2 DVT and O_2 DVT tanks to meet the latest configuration's functional end item requirements, i.e. incorporate hardware and avionics changes that have occurred since original assembly. This activity has been successfully completed.

7.2 SOW Scope of Work (2.0). The following paragraphs on the Program Work Breakdown Structure and the Schedule have been included for completeness.

7.2.1 Work Breakdown Structure (2.1). The WBS and the contract baseline were established by the completion of negotiations and submittal number 1 of the NASA 533P and 533Q reports on 2 August 1991. Figure A.1 in Appendix A is the second level program WBS.

7.2.2 Program Schedule (2.2). Figure A.2 in Appendix A is the PRSA Master schedule which depicts the top level of the DVT tank refurbishment with the other active PRSA programs. Figure A.3 is the DVT tank refurbishment schedule. It shows the original baseline plan, and the progress against it, for the activities relevant to each WBS. The baseline plan was not updated upon receipt of authorized changes to the contract completion date, although those dates are noted on the schedule.

7.3 SOW Technical Requirements (3.0). All technical requirements were met. All drawings, specifications, and procedures used were of the latest revision utilized under the OV-105 PRSA tank production program. Updates to these documents were done in the form of redlines to the applicable document and are collected in BECD Modification Drawings 163502 for the H_2 DVT Tank Assembly, 163504 for the O_2 Signal Conditioner Assembly, and 163506 for the O_2 DVT Tank Assembly. Each are included in the EIAD[9].

7.3.1 SOW PRSA H_2 DVT Tank (3.1). The technical requirements of the H_2 DVT refurbishment effort included the use of MRB dispositioned (usable for engineering test) hardware, remaining SHT0005 components, and residual hardware from the Orbiter and EDO programs. No hardware from the Space Shuttle Program NSTS program were required. For a detailed listing of the actual build hardware used in the refurbishment (does not include reused hardware) BECD C&DM has included an ABCR in the EIAD[9]. The major components that were replaced or reused are listed in Table I for reference. As recommended in the proposal[3], the pressure vessel was not opened up, therefore all internal components were reused.

Table I. Summary of Major H_2 DVT Build Components

COMPONENT	STATUS	SOURCE
Outer Shells	removed and replaced	SHT0005
Signal Conditioner Assembly	CAT tested and reused	H_2 DVT†
DC-DC Converter Assembly	removed and replaced	new
Support Straps	removed and replaced	new
Suspension Hardware	removed and replaced	SHT0005 and new
Girth Ring	removed and replaced	SHT0005
Insulation Blankets	removed and replaced	new
Fill and Vent Tubes - Dog Leg Assemblies	removed and replaced	new
Interface Tubes	removed and replaced	new
Foam Block	removed and replaced	new
Vac Ion Pump	removed and replaced	new
Pinch-off Tube	removed and replaced	new
Burst Disc	removed and replaced	new

† See paragraph 7.3.3 for explanation.

7.3.2 SOW PRSA O_2 DVT Tank (3.2). The technical requirements of the O_2 DVT refurbishment effort included the use of MRB dispositioned (usable for engineering test) hardware, remaining SHT0005 components, and residual hardware from the Orbiter and EDO programs. No hardware from the Space Shuttle Program NSTS program were required. For a detailed listing of the actual build hardware used in the refurbishment (does not include reused hardware) BECD C&DM has included an ABCR in the EIAD[9]. The major components that were replaced or reused are listed in Table II for reference. As recommended in the proposal[3], the pressure vessel was not opened up, therefore all internal components were reused.

Table II. Summary of Major O_2 DVT Build Components

COMPONENT	STATUS	SOURCE
Outer Shells	reused	na
Signal Conditioner Assembly	refurbished	na
DC-DC Converter Assembly	removed and replaced	new
Support Straps	removed and replaced	new
Suspension Hardware	removed and replaced	SHT0005 and new
Girth Ring	reused	na
Insulation Blankets	removed and replaced	new
Fill and Vent Tubes - Dog Leg Assemblies	removed and replaced	new
Interface Tubes	removed and replaced	new
Foam Block	removed and replaced	new
Vac Ion Pump	removed and replaced	new
Pinch-off Tube	removed and replaced	new
Burst Disc	removed and replaced	new

7.3.3 SOW Instrumentation (3.3). Verification of the operation of all standard PRSA tank flight instrumentation was performed on the H_2 DVT and the O_2 DVT during their respective End Item Acceptance Testing. All testing was completed without incident.

Note that H_2 DVT testing was performed using H_2 Signal Conditioner Assembly S/N SHS0002, which was later determined to be the H_2 Qualification Unit. It was replaced with S/N SHS0001, the H_2 DVT Signal Conditioner Assembly. The H_2 DVT Signal Conditioner was tested per the Component Acceptance Test procedure, 163406, which it passed, and therefore found to not require refurbishment. As Signal Conditioners are Line Replaceable Units, replacement on the H_2 DVT Tank Assembly was not deemed a concern.

7.3.3.1 SOW External Multilayer Insulation Blanket (3.3.1). An External MLI Blanket was designed to be installed onto an H_2 configuration tank. The two piece blanket was fabricated using 25 layers of 0.25 double aluminized mylar (BMS 17.15, Type XXVII) and netting (BMS 17.22, Type I) as the MLI, a Beta Cloth exterior, and Velcro® for assembling the two pieces together. The Blanket was shipped on 29 October 1992.

7.3.4 SOW Connectors (3.4). All mating mechanical and electrical connectors required to interface with the H_2 DVT were packaged with the EIAT Test Fixtures which were shipped concurrently with the H_2 DVT tank. These connectors and components are listed in Table III.

Table III. H_2 DVT Interface Connectors

PART NUMBER	PART NAME	QUANTITY
NB6GE14-4SNT	Plug, P1, H_2	1
NB6GE14-4SWT	Plug, P2, H_2	1
NB6GE16-26SNT	Plug, P3, H_2	1
NBS6GE8-3SN	Plug, P4, H_2	1
NBS6GE8-3SA	Plug, P5, H_2	1
R44150N-06U	Fitting, Supply, H_2	1
R44150N-10U	Fitting, Fill and Vent, H_2	2

All mating mechanical and electrical connectors required to interface with the O_2 DVT were packaged with the EIAT Test Fixtures which were shipped concurrently with the H_2 DVT Tank. These connectors and components are listed in Table IV.

Table IV. O_2 DVT Interface Connectors

PART NUMBER	PART NAME	QUANTITY
ME414-0235-7250	Plug, P1, O_2	1
ME414-0235-7251	Plug, P2, O_2	1
NB6GE16-26SNT	Plug, P3, O_2	1
NBS6GE8-3SN	Plug, P4, H_2	1
NBS6GE8-3SA	Plug, P5, H_2	1
R44150N-06U	Fitting, Supply, H_2	1
R44150N-10U	Fitting, Fill and Vent, H_2	2

7.3.5 SOW End-Item Acceptance Test Fixtures (3.5). One H_2 EIAT fixture, tool number T7479265, and one O_2 EIAT fixture, tool number T7479264, were fabricated and were shipped concurrently with the H_2 DVT Tank.

7.4 SOW Acceptance and Checkout Testing (4.0). End Item Acceptance Testing was performed to the latest revision of the procedure (H_2 DVT - BECD drawing 163414, revision N, and O_2 DVT - BECD drawing 163461, revision J), except that due to the shorter H_2 Quantity Gauge Probe, Table II of the H_2 procedure was redlined to correct the H_2 Signal Conditioner System Output voltage and the Quantity Capacitance. Note that the output voltage is within the ±2% of full scale accuracy requirement[4], and the tank passed EIAT without incident. See Table B.1 in Appendix B for a duplicate copy of this table. No changes were required for the shorter O_2 DVT Quantity Gauge Probe.

7.5 SOW Documentation (5.0). BECD Configuration and Data Management assembled and provided all EIAT data, MRB analyses, and other necessary documentation in their respective EIAD[9] with the delivery of the H_2 DVT tank and the O_2 DVT tank.

7.6 SOW Safety, Reliability, and Quality Assurance (6.0). Safety, reliability, and quality assurance requirements for the O_2 and H_2 DVT as specified in the PRSA Quality Assurance Control Plan (CR0009-1037) and PRSA Quality Work Instructions (QWI No. 2772) were utilized.

7.7 Additional Comments. Additional technical information and comments are included for completeness of the refurbishment activity.

7.7.1 O_2 Heater Element Insulation Resistance Test Failure. During production in-process testing of the heater element wiring, the insulation resistance was found to be below spec. After four months of extensive rework, evaluation, and testing it was determined that moisture was present in the heater element cold leads. Externally applied heat, activation of the heater element current, and pump-purge cycles using helium for the next three months were used to "draw out" the moisture permitting the insulation resistance to meet or exceed the 500

Meg-ohms requirement. Figure 1 illustrates the gradual improvement in heater element insulation resistance over the course of the 38 days a vacuum was applied. The heater element was turned on during work hours, only, after 25 days. Initially, the activation of the heater element appeared to be detrimental to the insulation resistance. However, the long term trend was a faster rate of improvement. Engineering required that the insulation resistance value far exceed the 500 Meg-ohms requirement to ensure that a repeat of previously observed "sudden insulation resistance drop-offs" did not occur.

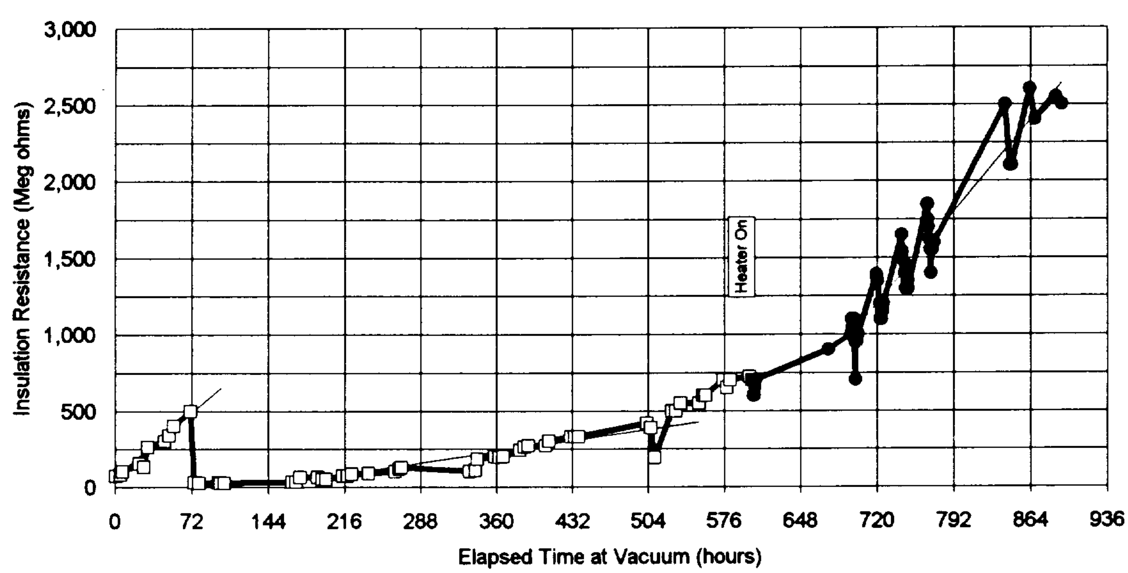

Figure 1. O_2 DVT J2 Heater Element Recovery History

7.7.2 Vacuum Acquisition. During the course of fabrication and production testing, the vacuum acquisition of the annulus of both the H_2 and O_2 DVT required extensive "cleaning" efforts due to contaminants left over from previous activities. For example, the H_2 DVT tank annulus was exposed to atmosphere while filled with cryogen while strain gauges and other test equipment were assembled inside the annulus for the strap investigation. The "cleaning" included numerous pneumatic sweeps of the vacuum annulus using dry GN_2 followed by a vacuum pumpdown cycle. Based upon a review of all previous BECD fabricated hydrogen tanks, using the "vacuum decay" data as a criteria, the vacuum annulus in this H_2 DVT tank is now one of the cleanest to date, as illustrated in Figure 2. The vacuum annulus of the O_2 DVT tank is nominally within the range of all of the BACG-built flight tanks, as illustrated in Figure 3.

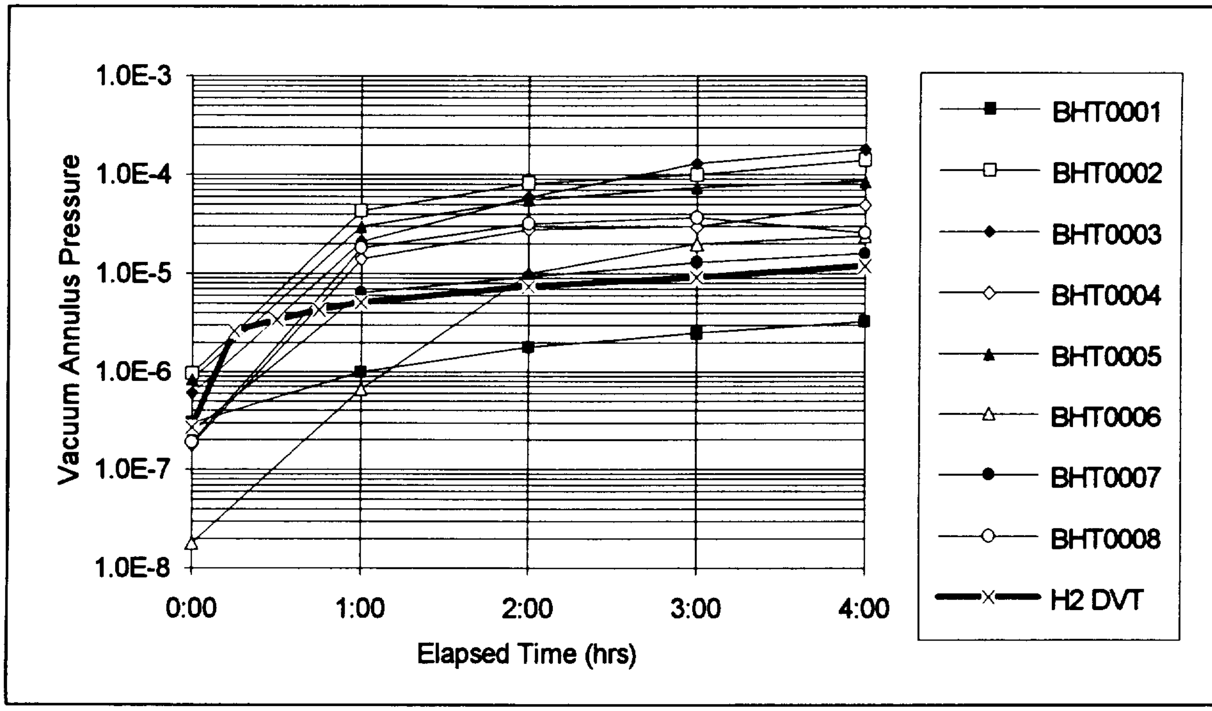

Figure 2. Hydrogen PRSA Tank Vacuum Decay History

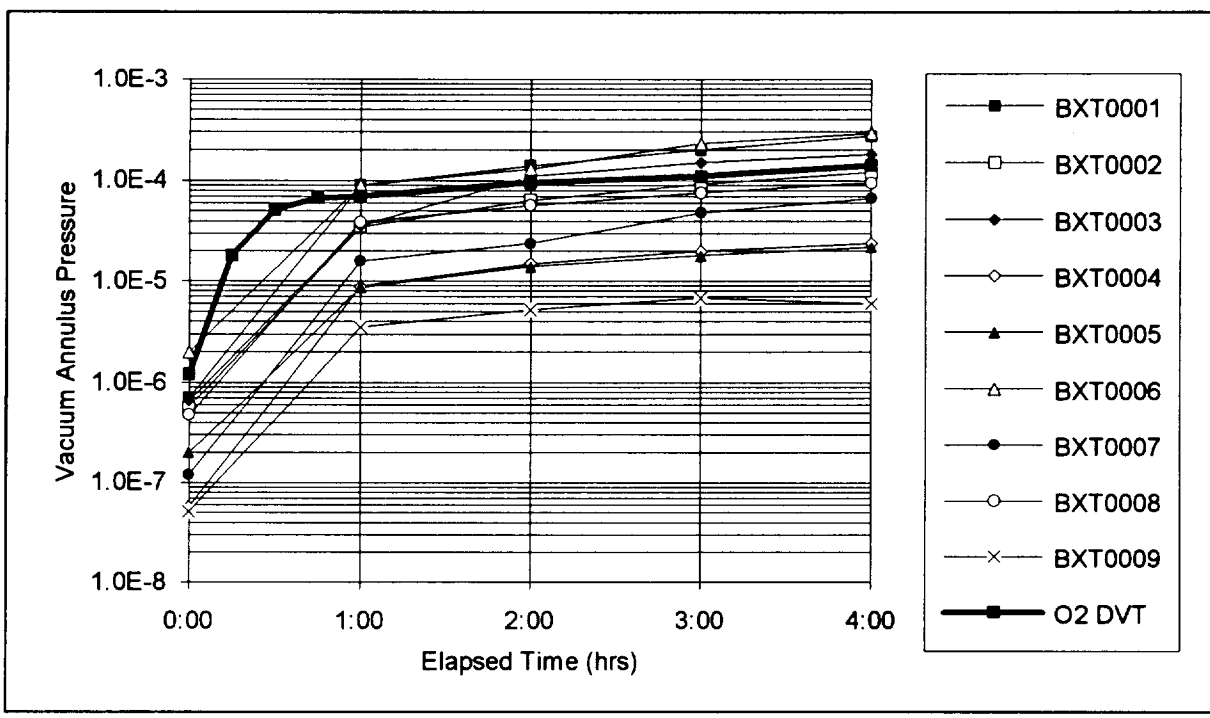

Figure 3. Oxygen PRSA Tank Vacuum Decay History

Vacuum decay data are a measure of the cleanliness and integrity of the vacuum annulus. After cool-down and before pinch-off, the vacuum annulus is isolated from the vacuum pump station and the vacuum annulus pressure monitored. The slower the rate of pressure change and the lower the pressure after four hours, the better the integrity of the vacuum annulus. Note that for flight builds, data are only taken at one hour increments for the four hours.

7.7.3 Removal and Replacement of H_2 DVT Girth Ring. Prior to refurbishment of the H_2 DVT, concerns with respect to the reuse of the existing Girth Ring versus replacement with the Girth Ring from SHT0005 existed. Following review and analysis by Program Administration, Project Engineering, and Materials and Processes Engineering, it was determined that the best course of action was to remove the original H_2 DVT Girth Ring and replace it with the Girth Ring from SHT0005. The principle rationale being that the ". . . use [of] a new Girth Ring [would] limit the opportunities to damage wires."[10]

7.7.4 H_2 Signal Conditioner. During a documentation review prior to shipment of the H_2 DVT Tank Assembly, it was discovered that the Tank had been End Item Acceptance Tested using Signal Conditioner S/N SHS0002, the original BAC PRSA Qualification Tank's Signal Conditioner. Following research into the sequence of events dating back to 1987, it was determined that the Signal Conditioners for the H_2 DVT Tank and the BAC Qual Tank had been switched. As a result, BECD had refurbished the BAC Qual Tank Signal Conditioner instead of the H_2 DVT Tank Signal Conditioner (S/N SHS0001).

A component acceptance test was performed on the H_2 DVT Signal Conditioner that indicated refurbishment was not required. The H_2 DVT Signal Conditioner was then assembled to the Tank and limited electrical checks performed to verify installation. The Qual Signal Conditioner was reidentified and assembled to the Qual Tank. As the Signal Conditioners are Line Replaceable Units, no further action was deemed warranted.

7.7.5 O_2 Electrical Deviations. The No. 2 element on the No. 2 Heater Assembly was tested during the course of normal fabrication and found to have a higher than specified resistance across J1-C to J1-D (3.881 ohms versus 3.39 to 3.72 ohms). Also, the Quantity Gauge Probe capacitance was measured at 168.85 pF versus 169.25 to 169.75 pF, specified. These measurements confirmed pre-existing conditions which do not compromise the intended function of the Tank Assembly. The operation of heater No. 2 at a higher bus voltage (e.g., 30 Vdc) will compensate for the higher resistance. The Quantity Gauge Probe is from the original manufacture of the Tank when the Probes were shorter in length. However, the change in the output from the Signal Conditioner was found to be negligible during EIAT such that no adjustments are required.

7.7.6 Time and Cycle History. An extensive research effort was conducted to determine the actual pressure time and cycle history of the H_2 and O_2 DVT tanks. These data are presented in Table C.1 and C.2, respectively, in Appendix C. These data include activities at Beech Aircraft Corporation, prior to their acquisition by BASG, activities at JSC, Vandenburg, and Rockwell - Downey. Some data were not available at the time this report was prepared. The available data are considered to be 95% accurate since some of them are from the memory of individuals involved in the testing at that time.

7.7.7 Vacuum Maintenance. BECD continues to recommend that vacuum maintenance of the tanks' vacuum annulus be performed every 30 days[11].

8. REFERENCES and BIBLIOGRAPHY

[1] The H_2 DVT was never assigned a RI part number, though it was originally built to meet the requirements of the MC282-0063-0200 pre-foaming configuration or the V070-454852-002 post-foaming configuration.

[2] The O_2 DVT was not assigned a RI part number originally, though it was built to meet the requirements of the MC282-0063-0100 pre-foaming configuration or the V070-454853-002 post-foaming configuration. Shortly thereafter, it was reworked to a MC282-0063-0300 pre-foam configuration.

[3] BASG Proposal No. P90-957, Volume 1 (November 1990), "Proposal for Refurbishment of PRSA Liquid Hydrogen DVT Tank and Liquid Oxygen DVT Tank

[4] Rockwell International Specification MC282-0112 (21 May 1987), "Storage Assembly, Power Reactant - Orbiter," paragraph 3.2.1.2.3

[5] BECD Letter BR-9202-25 (27 February 1992), "Contract NAS9-18398 - O2 DVT Tank Heater and Probe Electrical Values"

[6] NASA JSC Letter EP5-92-L33 (received 16 March 1992), from Howard Wagner to Marc Desgalier

[7] Rockwell International Specification MC282-0112 (21 May 1987), "Storage Assembly, Power Reactant - Orbiter," paragraph 4.2.3.1.11

[8] NASA JSC Statement of Work, Contract No. NAS9-18398

[9] BECD H_2 DVT End Item Acceptance Data-Package No. CR0009-6018 and BECD O_2 DVT End Item Acceptance Data-Package No. CR0009-6019.

[10] BECD Letter BR-9111-35 (25 November 1991), "Contract NAS9-18398 - H2 DVT Tank Girth Ring Replacement"

[11] Beech Aircraft Corporation Engineering Report No. ER 16593G (28 April 1983), "Limited Life List", Table I

9. APPENDICES

9.1 Appendix A. The second level WBS is illustrated in Figure A.1. Figure A.2 illustrates the PRSA Master schedule with the top level of the DVT tank refurbishment overlaid with other active PRSA programs. Figure A.3 is the original DVT tank refurbishment schedule with authorized changes noted.

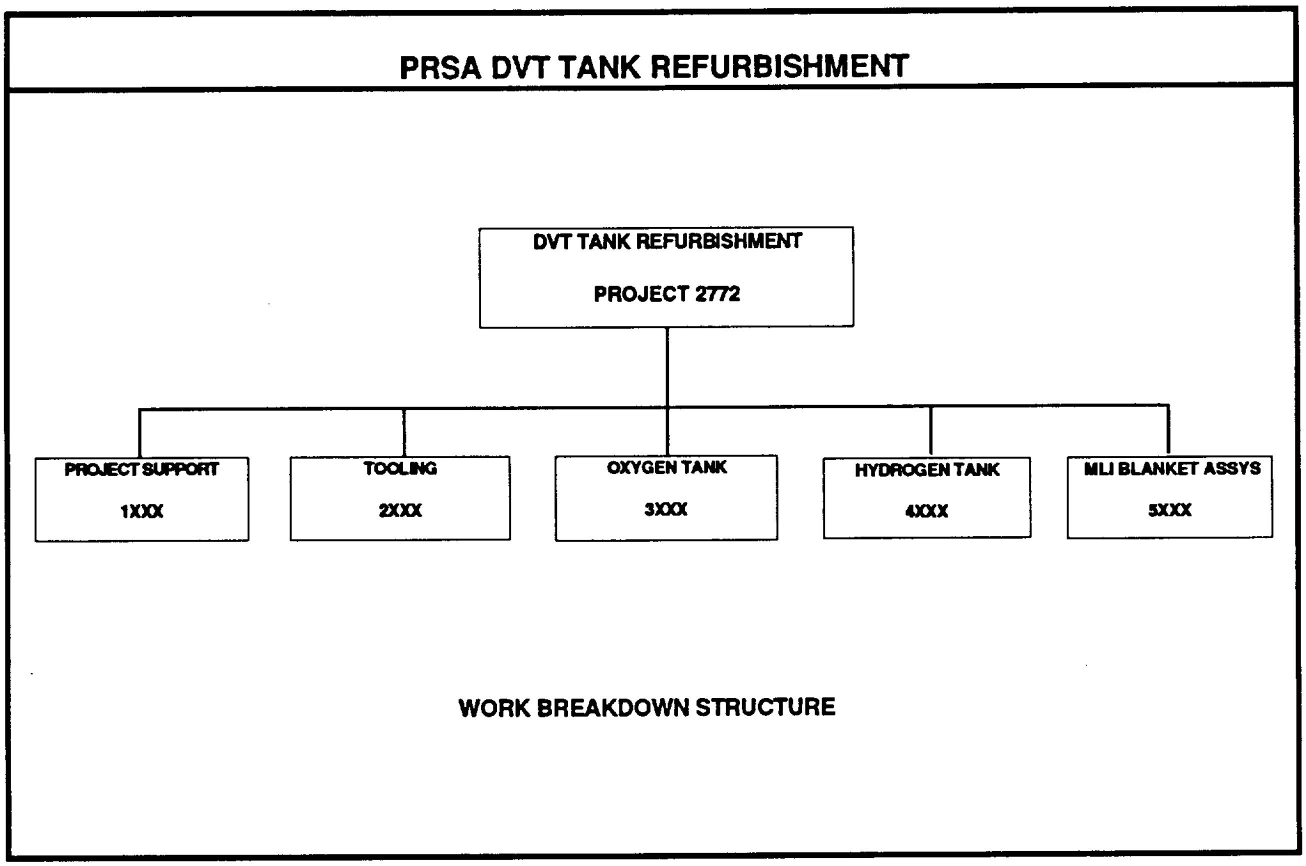

Figure A.1 DVT Refurbishment Work Breakdown Structure

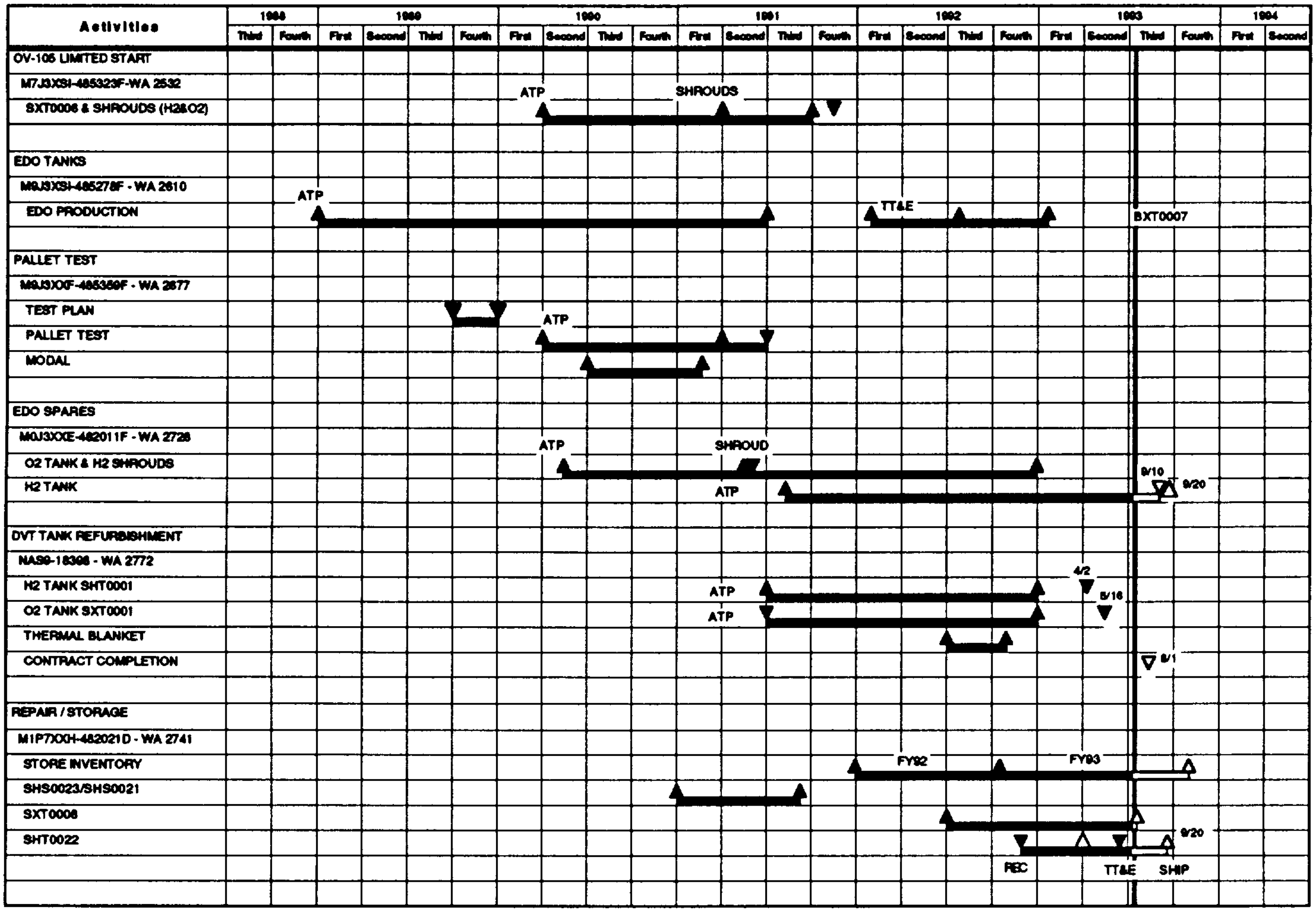

Figure A.2 PRSA Master Schedule

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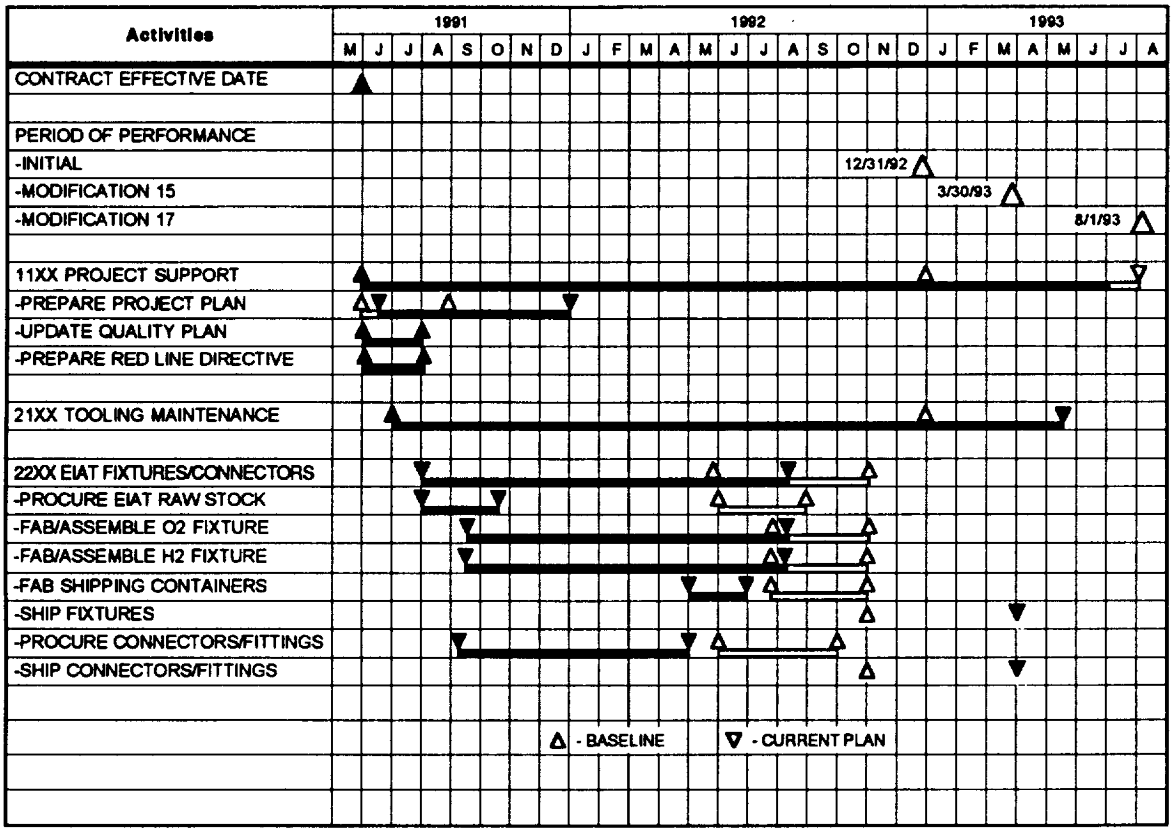

FIGURE A.3 DVT REFURBISHMENT SCHEDULE

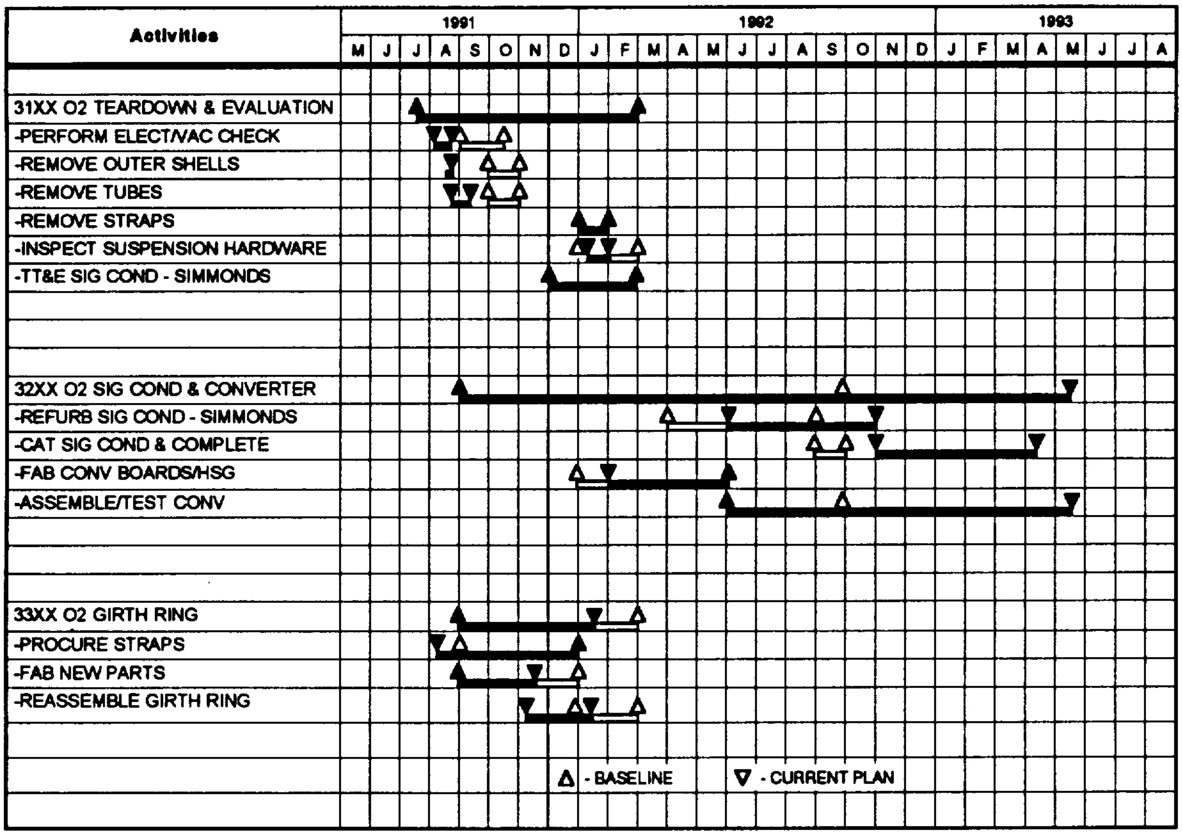

Figure A.3 DVT Refurbishment Schedule (continued)

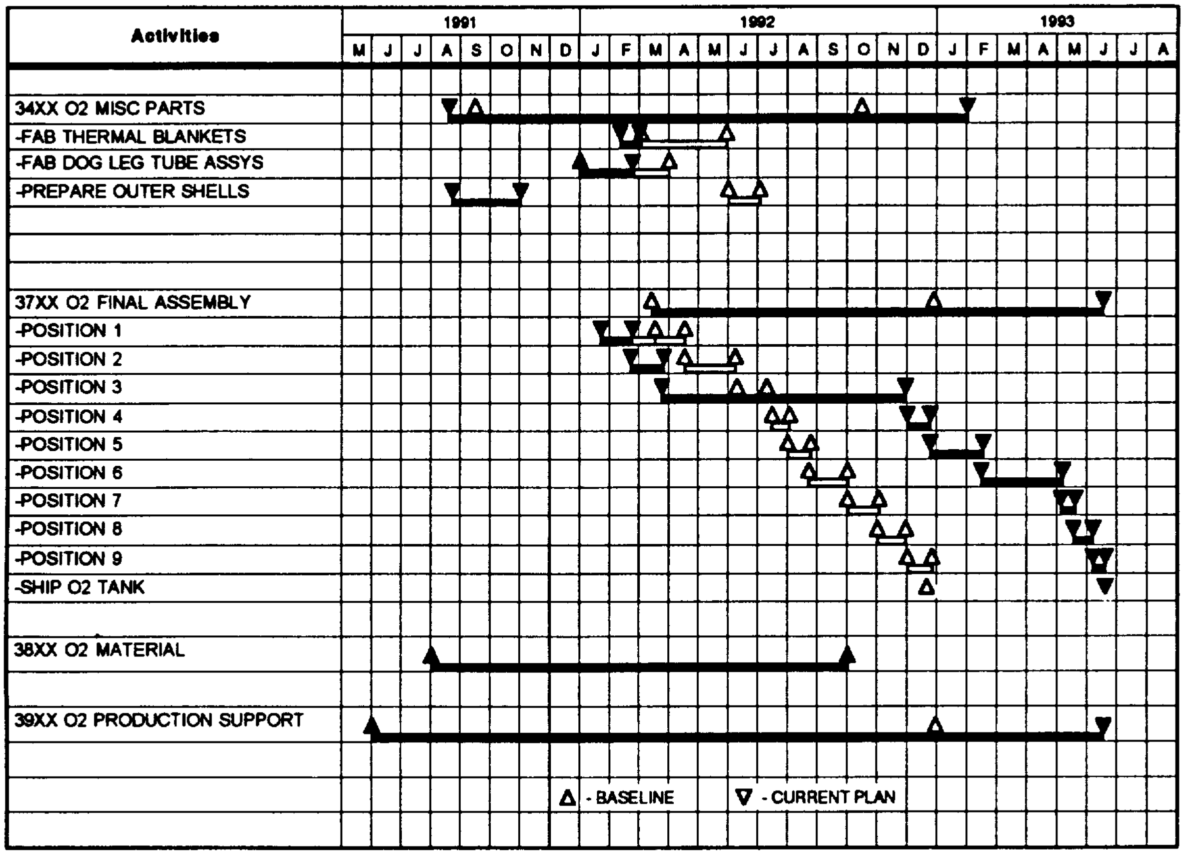

Figure A.3 DVT Refurbishment Schedule (continued)

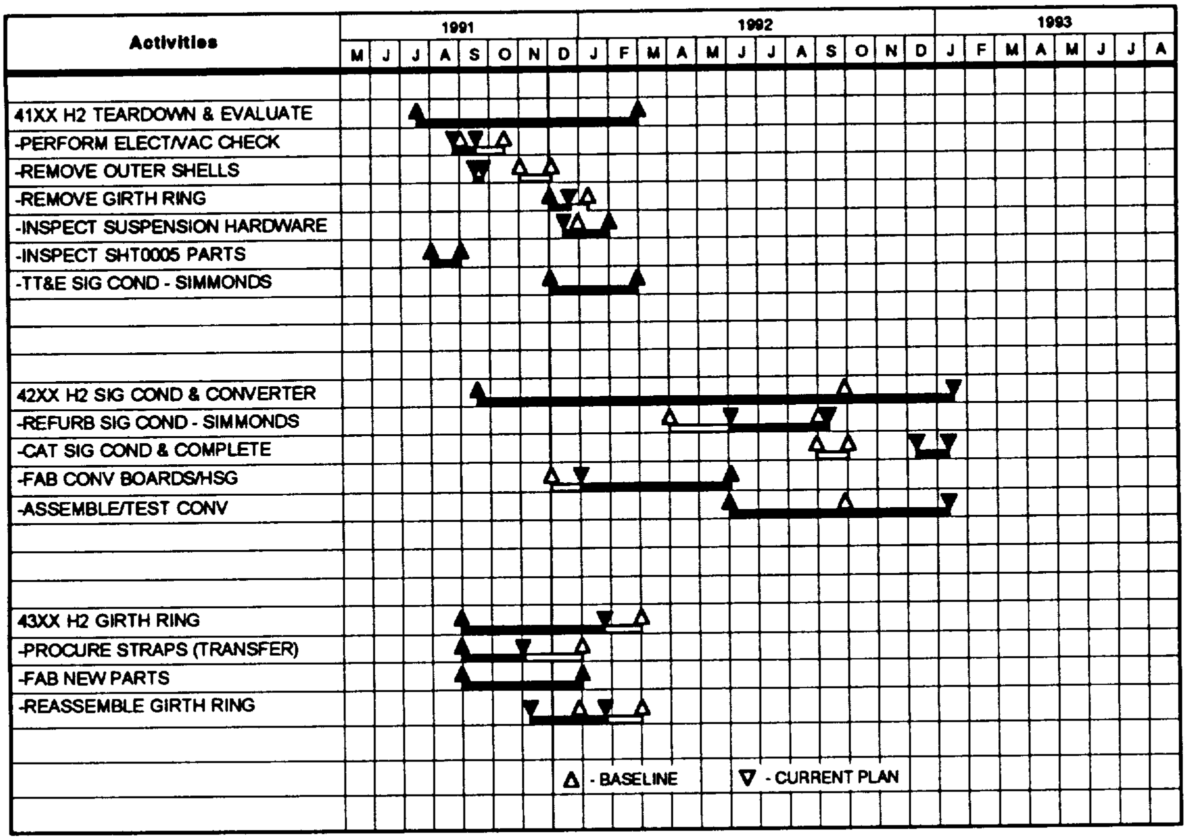

Figure A.3 DVT Refurbishment Schedule (continued)

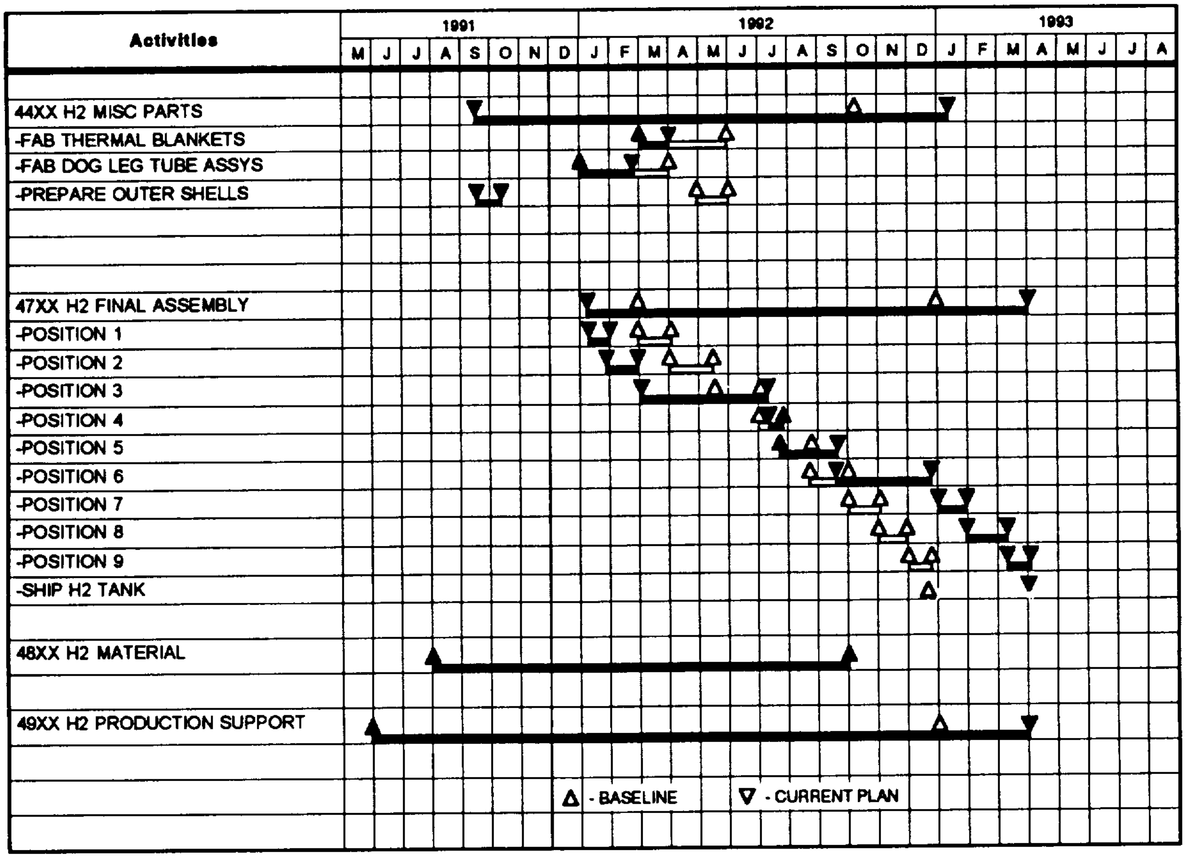

Figure A.3 DVT Refurbishment Schedule (continued)

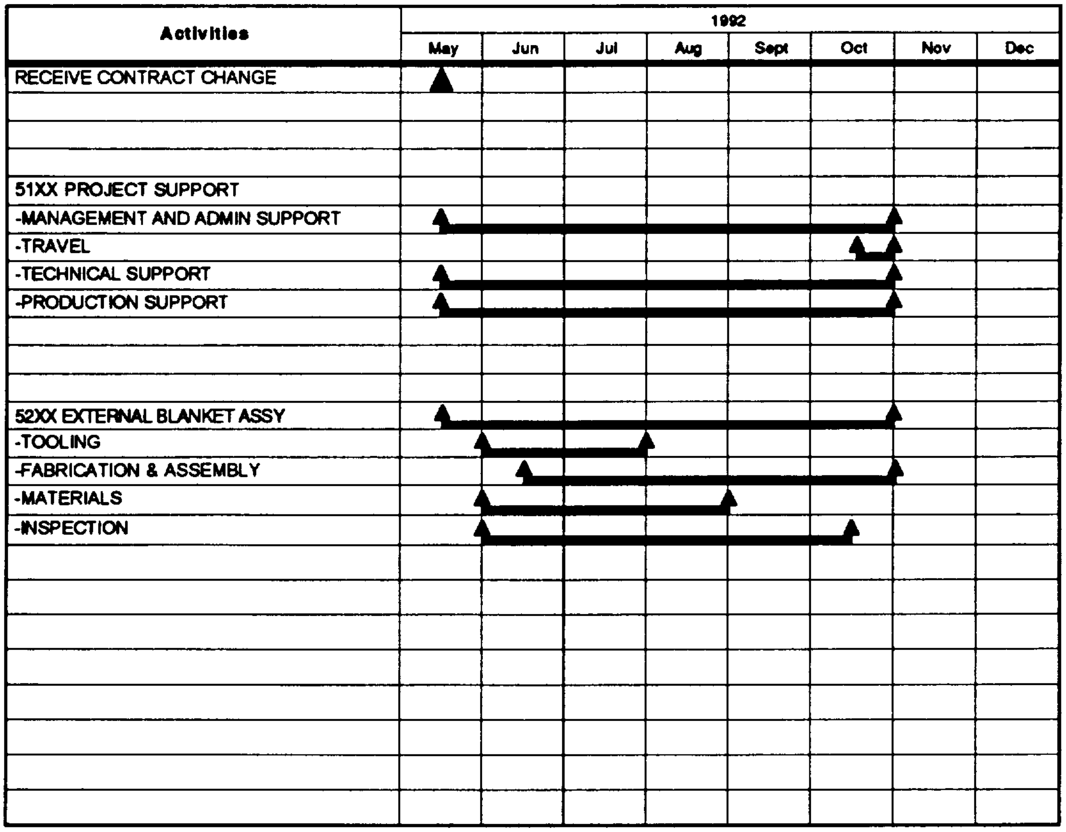

Figure A.3 DVT Refurbishment Schedule (continued)

9.2 Appendix B. H_2 Signal Conditioner Output and Quantity Capacitance. The EIAT procedure was redlined to accommodate the shorter H_2 Quantity Gauge Probe. The following table is a reproduction of these redlines. Note that the output voltage is within the ±2% of full scale accuracy requirement (±0.100 Vdc).

Table B.1 Corrected H_2 Signal Conditioner Output and Quantity Capacitance

Signal Conditioner System Output (Vdc)		Quantity Capacitance (lb)	Quantity Capacitance (pF)	
~~5.000~~	4.948	96.30	~~261.532~~	260.990
~~4.774~~	4.722	92.00	~~259.163~~	258.621
~~4.500~~	4.448	86.51	~~256.125~~	255.583
~~4.000~~	3.948	76.28	~~250.669~~	250.127
~~3.500~~	3.448	66.25	~~245.270~~	244.728
~~3.000~~	2.948	56.02	~~240.019~~	239.431
~~2.500~~	2.448	45.82	~~234.767~~	234.225
~~2.000~~	1.948	35.81	~~229.670~~	229.087
~~1.500~~	1.448	25.58	~~224.573~~	224.031
~~1.000~~	0.948	15.35	~~219.579~~	219.010
~~0.500~~	0.448	5.35	~~214.642~~	214.100
~~0.360~~	0.308	2.30	~~213.219~~	212.677

Copied from redlined 163414, duplicate in BECD Modification Drawing 163502.

9.3 Appendix C. H_2 DVT Pressure Time and Cycle History. Table C.1 lists the known and suspected pressure times and cycles for the H_2 DVT tank from original assembly to present.

Table C.1 H_2 DVT Pressure Time and Cycle History

SD/SCD No MC282-0063-0300 S/N 07399000SHT0001
SD Spec MC282-0063H Ball Contract # NAS9-18398
Beech P/N 15548-0116-1 Ball Mod 163502-500 Mar 1993 13993

	HOURS		CYCLES		
EVENT	AMB	CRYO	AMB	CRYO	DATE
1st EIAT	2.1	408.0	1.0	1.0	10/17/77 - 3/11/77
Thermal Acoustic Oscillations DVT	0.0	195.0	0.0	1.0	3/11/77 - 11/11/77
Orifice Development	3.0	432.0	2.0	8.0	6/12/77 - 4/4/78
Orifice Development	3.4	382.0	4.0	6.0	6/1/78 - 8/23/78
Qual Acceleration Tests	2.5	9.9	5.0	5.0	9/21/78 - 11/10/78
External Components Vibration w/ Freon 13/GN_2	585.0	0.0	2.0	0.0	1/15/79 - 2/8/79
EIAT	3.2	72.0	2.0	2.0	2/13/79 - 2/16/79
H_2 DVT Tests	1.0	56.2	1.0	1.0	2/22/79 - 2/28/79
1st Mission Simulation	2.2	201.0	2.0	2.0	9/22/79 - 10/1/79
2nd Mission Simulation	-	210.0	-	2.0	10/15/79 - 10/28/79
JSC	?	?	?	?	1/80 - 12/82
Mini EIAT	1.0	38.2	1.0	2.0	3/2/83 - 3/5/83
5th Tank Fill Verification	2.1	11.5	2.0	1.0	3/16/83 - 3/17/83
STS-9 Anomaly Fill Verification	1.1	52.2	1.0	2.0	10/21/83 - 10/26/83
STS-9 30 Hr Standby	1.0	32.8	1.0	1.0	10/26/83 - 10/27/83

Table C.1 H_2 DVT Pressure Time and Cycle History (continued)

SD/SCD No MC282-0063-0300 — S/N 07399000SHT0001
SD Spec MC282-0063H — Ball Contract # NAS9-18398
Beech P/N 15548-0116-1 — Ball Mod 163502-500 Mar 1993 13993

	HOURS		CYCLES		
EVENT	AMB	CRYO	AMB	CRYO	DATE
STS-9 Fill Anomaly Verification	1.0	182.0	1.0	3.0	10/30/83 - 11-/5/83
STS-9 4/5 Tank Fill/Mission Simulation	2.3	210.3	2.0	2.0	11/6/83 - 11/14/83
STS-9 Simultaneous Support	1.2	53.8	1.0	1.0	11/27/83 - 11/29/83
Phase "A" Over Fill	2.1	196.0	2.0	4.0	2/16/84 - 4/30/84
OV-102 Modification	1.1	18.1	1.0	1.0	6/8/84 - 6/13/84
Acceptance for Vandenburg	1.1*	20.0	1.0*	1.0	7/5/85 - 9/5/85
Acceptance at Vandenburg	2.6	50.0**	2.0	3.0**	9/17/85 - 10/85
Vacuum Loss	1.1	23.6	1.0	1.0	6/1/87 - 6/2/87
Strap Evaluation	1.0	51.0	1.0	1.0	10/26/88 - 11/1/88
Upside-down Tests (Jim Lester)	1.0	40.0	1.0	1.0	1988 - 1989
CRC Pad "B" Certification	2.3	68.1	2.0	2.0	6/29/89 - 9/11/89
CRC Pad "A" Certification	1.1	21.5	1.0	2.0	5/8/90 - 5/9/90
Rockwell - Downey, CA Freon 13 / GN_2	3.0	-	3.0	-	7/20/91 - 7/28/91
Refurbishment IAT	1.5	0	1.0	0	5/11/92
Refurbishment EIAT	0.6	75.7	1.0	1.0	1/27/93-2/3/93
TOTALS (APPROXIMATION)	630.6	3,110.9	45.0	57.0	

* Proof pressure of 365 psia for 3 minutes
** No data exists, this is memory data only (≈ 95% accurate)

O_2 DVT Pressure Time and Cycle History. Table C.2 lists the known and suspected pressure times and cycles for the O_2 DVT tank from original assembly to present.

Table C.2 O_2 DVT Pressure Time and Cycle History

SD/SCD No MC282-0063-0100 SD Spec MC282-0063H Beech P/N 15548-0115-1			S/N 07399000SXT0001 Ball Contract # NAS9-18398 Ball Mod 163506-500 May 1993 13993		
	Hours		Cycles		
Event	Amb	Cryo	Amb	Cryo	Date
DVT Vibration	1.0	56.0	1.0	2.0	11/30/77 - 12/1/77
EIATs	1.2	175.0	1.0	4.0	3/4/78 - 3/22/78
Acceleration	2.0	19.5	1.0	3.0	7/10/78 - 7/17/78
EIAT	2.0	48.0	2.0	1.0	11/6/78 - 11/7/78
1st Mission Simulation	1.5	211.0	4.0	1.0	8/4/79 - 8/13/79
2nd Mission Simulation	-	224.0	-	2.0	8/23/79 - 8/30/79
JSC Testing 1982	?	?	?	?	1982
TK 5 Fill Verification	6.0	18.0	3.0	1.0	3/11/83 - 3/18/83
STS-9 4/5	4.0	164.0	2.0	3.0	10/28/83 - 11/5/83
STS-9 50 hour standby	5.0	58.0	1.0	1.0	11/17/83 - 11/23/83
STS-9 Simultaneous	3.3	20.0	2.0	1.0	11/27/83 - 11/29/83
OV-102 Modification	2.0	26.0	1.0	3.0	5/22/84 - 5/25/84
Over Fill Phase A	2.0	3.5	1.0	1.0	7/5/84 - 7/12/84
Over Fill Phase II	2.0	48.0	1.0	6.0	9/5/84 - 9/11/84
Acceptance for Vandenburg*	2.1*	4.0	1.0*	1.0	6/17/85
Acceptance at Vandenburg	1.2	50.0**	1.0	3.0**	12/14/85 - 1/86
O_2 Certification	1.5	148.0	2.0	2.0	7/11/86 - 7/19/86

Table C.2 O_2 DVT Pressure Time and Cycle History (continued)

SD/SCD No	MC282-0063-0100	S/N	07399000SXT0001
SD Spec	MC282-0063H	Ball Contract #	NAS9-18398
Beech P/N	15548-0115-1	Ball Mod	163506-500 May 1993 13993

	HOURS		CYCLES		
EVENT	AMB	CRYO	AMB	CRYO	DATE
CRC - B EIAT Certification	3.0	36.6	2.0	2.0	7/8/88 - 7/19/88
JSC Testing 1988	?	?	?	?	7/88 - 1991
Refurbishment IAT	1.5	0	1.0	0	4/3/93
Refurbishment EIAT	1.1	97.0	1.0	1.0	5/17/93-5/21/93
TOTALS (APPROXIMATION)	42.4	1,406.6	28.0	38.0	

* Proof pressure of 1155 psia for 3 minutes

** No data exists, this is memory data only (≈ 95% accurate)